CLAIMS

What is claimed is:

1. An active material for a battery having a surface-treatment layer, comprising a compound of the formula (1):

MXO_k (1)

wherein M is at least one element selected from the group consisting of an alkali metal, an alkaline earth metal, a group 13 element, a group 14 element, a transition metal, and a rare-earth element,

X is an element that is capable of forming a double bond with oxygen, and

k is a numerical value in the range of 2 to 4.

2. The active material of claim 1, wherein the element M is selected from the group consisting of Na, K, Mg, Ca, Sr, Ni, Co, Si, Ti, B, Al, Sn, Mn, Cr, Fe, V, Zr, and a combination thereof.

3. The active material of claim 1, wherein the element X is selected from the group consisting of P, S, W, and a combination thereof.

4. The active material of claim 1, wherein an amount of the element M is 0.1 to 15 % by weight of the active material.

5. The active material of claim 1, wherein an amount of the element M is 0.1 to 6% by weight of the active material.

6. The active material of claim 1, wherein an amount of the element X is 0.1 to 15 % by weight of the active material.

7. The active material of claim 1, wherein an amount of the element X is 0.1 to 6% by weight of the active material.

8. The active material of claim 1, wherein a thickness of the surface-treatment layer is 0.01 to 2 μm.

9. The active material of claim 1, wherein a tap density of the active material is 1 to 3 g/cc.

10. The active material of claim 1, wherein the active material is an electrochemically reversibly oxidizable and reducible material.

11. The active material of claim 10, wherein the electrochemically oxidizable and reducible material is selected from the group consisting of a metal, a lithium-containing alloy, a sulfur-based compound, a compound that can reversibly form a lithium-containing compound by a reaction with lithium ions, and a material that can reversibly intercalate/deintercalate lithium ions.

12. The active material of claim 11, wherein the material that can reversibly intercalate/deintercalate lithium ions is one of lithium-containing metal oxide, a lithium containing chalcogenide compound, and a carbon-based material.

13. The active material as recited in claim 1, wherein the active material is used in at least one of a positive electrode and a negative electrode of the battery.

14. The active material as recited in claim 1, wherein the battery is one of a manganese battery, an alkaline battery, a mercury battery, a silver oxide battery, a lead-acid storage battery, a nickel metal hydride battery, a nickel-cadmium battery, a lithium metal battery, a lithium ion battery, a lithium polymer battery and a lithium-sulfur battery.

15. An active material for a battery, comprising:

a lithiated intercalation compound selected from the group consisting of a lithium-containing metal oxide and a lithium-containing chalcogenide compound; and

a surface-treatment layer is formed on a surface of the lithiated intercalation compound and has a solid-solution compound including surface treating elements M and X, and a compound of the formula (1):

MXO_k (1)

wherein M is at least one element selected from the group consisting of an alkali metal, an alkaline earth metal, a group 13 element, a group 14 element, a transition metal, and a rare-earth element,

X is an element which is capable of forming a double bond with oxygen, and

k is a numerical value in the range of 2 to 4.

16. The active material of claim 15, wherein the element M is selected from the group consisting of Na, K, Mg, Ca, Sr, Ni, Co, Si, Ti, B, Al, Sn, Mn, Cr, Fe, V, Zr, and a combination thereof.

17. The active material of claim 15, wherein the element X is selected from the group consisting of P, S, W, and a combination thereof.

18. The active material of claim 15, wherein an amount of the element M is 0.1 to 15% by weight of the active material.

19. The active material of claim 15, wherein an amount of the element M is 0.1 to 6% be weight of the active material.

20. The active material of claim 15, wherein an amount of the element X is 0.1 to 15 % by weight of the active material.

21. The active material of claim 15, wherein an amount of the element X is 0.1 to 6% by weight of the active material.

22. The active material of claim 15, wherein a thickness of the surface-treatment layer is 0.01 to 2 μm.

23. The active material of claim 15, wherein a tap density of the active material is 1 to 3 g/cc.

24. The active material of claim 15, wherein a concentration of the elements M and X decreases gradually from a surface to a center of a particle grain of the active material.

25. The active material of claim 15, wherein the lithiated intercalation compound has one of a monoclinic, hexagonal and a cubic structure as a basic structure.

26. The active material of claim 15, wherein the lithiated intercalation compound is at least one selected from the group consisting of a lithium compound with the following formulas (2) to (14):

$Li_xMn_{1-y}M'_yA_2$ (2)

$Li_xMn_{1-y}M'_yO_{2-z}B_z$ (3)

$Li_xMn_2O_{4-z}B_z$ (4)

$Li_xMn_{2-y}M'_yA_4$ (5)

$Li_xCo_{1-y}M'_yA_2$ (6)

$Li_xCo_{1-y}M'_yO_{2-z}B_z$ (7)

$Li_xNi_{1-y}M'_yA_2$ (8)

$Li_xNi_{1-y}M'_yO_{2-z}B_z$ (9)

$Li_xNi_{1-y}Co_yO_{2-z}B_z$ (10)

$Li_xNi_{1-y-z}Co_yM'_zA_\alpha$ (11)

$Li_xNi_{1-y-z}Co_yM'_zO_{2-\alpha}B_\alpha$ (12)

$Li_xNi_{1-y-z}Mn_yM'_zA_\alpha$ (13)

$Li_xNi_{1-y-z}Mn_yM'_zO_{2-\alpha}B_\alpha$ (14)

wherein $0.95 \leq x \leq 1.1$, $0 \leq y \leq 0.5$, $0 \leq z \leq 0.5$, and $0 < \alpha \leq 2$;

M' is at least one element selected from the group consisting of Al, Ni, Co, Mn, Cr, Fe, Mg, Sr, V, and a rare-earth element;

A is at least one element selected from the group consisting of O, F, S and P; and

B is at least one element selected from the group consisting of F, S and P.

27. The active material of claim 26, wherein an average particle size of the lithiated intercalation compound is 1 to 20 *μm*.

28. An active material for a battery, comprising:

a lithiated intercalation compound selected from the group consisting of a lithium-containing metal oxide and a lithium-containing chalcogenide compound; and

a surface-treatment layer formed on a surface of the lithiated intercalation compound and has a solid-solution compound including Al and P, and an $AlPO_k$ (k is 2 to 4) compound.

29. The active material of claim 28, wherein an amount of the element Al is 0.1 to 15 % by weight of the active material.

30. The active material of claim 28, wherein an amount of the element Al is 0.1 to 6% by weight of the active material.

31. The active material of claim 28, wherein an amount of the element P is 0.1 to 15 % by weight of the active material.

32. The active material of claim 28, wherein an amount of the element P is 0.1 to 6% by weight of the active material.

33. The active material of claim 28, wherein a concentration of the elements M and X decreases gradually from a surface to a center of a particle grain of the active material.

34. The active material of claim 28, wherein the lithiated intercalation compound has one of a monoclinic, hexagonal and a cubic structure as a basic structure.

35. The active material of claim 28, wherein the lithiated intercalation compound is at least one selected from the group consisting of a lithium compound with the following formulas (2) to (14):

$Li_xMn_{1-y}M'_yA_2$ (2)

$Li_xMn_{1-y}M'_yO_{2-z}B_z$ (3)

$Li_xMn_2O_{4-z}B_z$ (4)

$Li_xMn_{2-y}M'_yA_4$ (5)

$Li_xCo_{1-y}M'_yA_2$ (6)

$Li_xCo_{1-y}M'_yO_{2-z}B_z$ (7)

$Li_xNi_{1-y}M'_yA_2$ (8)

$Li_xNi_{1-y}M'_yO_{2-z}B_z$ (9)

$Li_xNi_{1-y}Co_yO_{2-z}B_z$ (10)

$Li_xNi_{1-y-z}Co_yM'_zA_\alpha$ (11)

$Li_xNi_{1-y-z}Co_yM'_zO_{2-\alpha}B_\alpha$ (12)

$Li_xNi_{1-y-z}Mn_yM'_zA_\alpha$ (13)

$Li_xNi_{1-y-z}Mn_yM'_zO_{2-\alpha}B_\alpha$ (14)

wherein $0.95 \leq x \leq 1.1$, $0 \leq y \leq 0.5$, $0 \leq z \leq 0.5$, and $0 < \alpha \leq 2$;

M' is at least one element selected from the group consisting of Al, Ni, Co, Mn, Cr, Fe, Mg, Sr, V, and a rare-earth element;

A is at least one element selected from the group consisting of O, F, S and P; and

B is at least one element selected from the group consisting of F, S and P.

36. The active material of claim 35, wherein an average particle size of the lithiated intercalation compound is 1 to 20 *μm*.

37. The active material of claim 28, wherein a tap density of the active material is 1 to 3 g/cc.

38. A method of preparing an active material for a battery, comprising:

preparing a coating liquid by adding a compound including an element that is capable of forming a double bond with oxygen of lithium metal oxide, and a metal compound comprising at least one element from the group consisting of an alkali metal, an alkaline earth metal, a group 13 element, a group 14 element, a transition metal, and a rare-earth element, to water;

adding active material to the coating liquid to coat the active material; and

heat-treating the coated active material to form a surface-treatment layer comprising a compound having the formula (1):

MXO_k (1)

wherein M is at least one element selected from the group consisting of an alkali metal, an alkaline earth metal, a group 13 element, a group 14 element, a transition metal, and a rare-earth element,

X is an element that is capable of forming a double bond with oxygen, and

k is a numerical value in the range of 2 to 4.

39. The method of claim 38, wherein the element M is selected from the group consisting of Na, K, Mg, Ca, Sr, Ni, Co, Si, Ti, B, Al, Sn, Mn, Cr, Fe, V, Zr, and a combination thereof.

40. The method of claim 38, wherein the element X is selected from the group consisting of P, S, W, and a combination thereof.

41. The method of claim 38, wherein an amount of the element M is 0.01 to 30 % by weight of the coating liquid.

42. The method of claim 38, wherein an amount of the element M is 0.01 to 20% by weight of the coating liquid.

43. The method of claim 38, wherein an amount of the element X is 0.01 to 30 % by weight of the coating liquid.

44. The method of claim 38, wherein an amount of the element X is 0.01 to 20% by weight of the coating liquid.

45. The method of claim 38, wherein the active material is an electrochemically reversibly oxidizable and reducible material.

46. The method of claim 45, wherein the electrochemically oxidizable and reducible material is selected from the group consisting of a metal, a lithium-containing alloy, a sulfur-based compound, a compound that can reversibly form a lithium-containing compound by a reaction with lithium ions, and a material that can reversibly intercalate/deintercalate lithium ions.

47. The active material of claim 46 wherein the material that can reversibly intercalate/deintercalate lithium ions is one of lithium-containing metal oxide, a lithium-containing chalcogenide compound, and a carbon-based material.

48. The method of claim 38, wherein the heat-treating step is performed at 100 to 700°C.

49. The method of claim 38, wherein the heat-treating step is performed at 100 to 500°C.

50. The method of claim 38, further comprising, prior to the heating step, drying the coat formed on the active material.

51. The method of claim 38, wherein the heat treating step is performed for 1 to 20 hours.

52. A method of forming a battery, comprising:

preparing a coating liquid by adding a compound including an element that is capable of forming a double bond with oxygen of lithium metal oxide, and a metal compound comprising at least one element from the group consisting of an alkali metal, an alkaline earth metal, a group 13 element, a group 14 element, a transition metal, and a rare-earth element, to water;

adding active material to the coating liquid to coat the active material; and

heat-treating the coated active material to prepare an active material having a surface-treatment layer comprising a compound having the formula (1):

MXO_k (1)

wherein M is at least one element selected from the group consisting of an alkali metal, an alkaline earth metal, a group 13 element, a group 14 element, a transition metal, and a rare-earth element, X is an element that is capable of forming a double bond with oxygen, and k is a numerical value in the range of 2 to 4;

coating a slurry comprising the active material with the surface treatment layer onto a current collector to prepare at least one of a positive and negative electrode; and

fabricating a battery using the prepared one of the positive and negative electrodes and a corresponding other one of the positive and negative electrodes.

53. The method of claim 52, wherein the active material is selected from electrically reversibly oxidizable and reducible materials.

54. The method of claim 52, wherein the battery is selected from a manganese battery, an alkaline battery, a mercury battery, a silver oxide battery, a lead-acid storage battery, a nickel metal hydride battery, a nickel-cadmium battery, a lithium metal battery, a lithium ion battery, a lithium polymer battery and a lithium-sulfur battery.